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**MULTI-BAND TRANSCEIVERS WITH REDUCED FREQUENCY SOURCES FOR
DIGITAL TRANSMISSIONS**

TECHNICAL FIELD

This invention relates to the architecture of communications equipment and; more particularly, to a system of minimizing the frequency sources and filters in communications transceivers.

BACKGROUND OF THE INVENTION

As the cellular and wireless communication industries continue to define themselves, the promulgation of various standards and protocols continue to plague the industry. This plague along with the partitioning of the frequency spectrum has assured the need for dual-band, dual-mode radio transceivers into the foreseeable future.

Some manufactures of radio telephone devices have succeeded in providing transceivers that are dual-mode (transceivers that support two or more protocols) and/or dual-band (transceivers that operate in multiple frequency ranges).

5 However, these dual-band, dual-mode transceivers have distinct
disadvantages which are addressed by the present invention.
Early versions of dual-band transceivers included two
transceivers that had the electronic components necessary to
operate in both bands. This was the equivalent of taking two
10 transceivers that operate in different bands and taping them
back-to-back. The inefficiencies of component usage, power
consumption, and the size were unacceptable.

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In today's dual-band radio transceivers, the components
of one band are shared to allow the transceiver to work in a
second band. One key to today's technology is to use an
oscillator (frequency source) that may be shifted between a
first and a second frequency range. The frequency range of
the frequency source is primarily a function of the band in
which the transceiver is transmitting or receiving. However,
prior art techniques have not fully reduced the number of
oscillators required in a dual-band transceiver to the level
achieved by the present invention. Thus, a first objective of
the present invention is to reduce the component count,
particularly the frequency sources and filters needed in a
25 dual-band transceiver.

In addition to the use of a multiple band frequency
source, a fixed second frequency source is utilized in some of
the techniques provided today. In some prior art
transmitters, the dual-band frequency source generates a first
30 oscillation frequency and the second frequency source
generates a second oscillating frequency. However, prior art
fails to utilize
the two oscillators for all the primary needs in both the
transmitter and the receiver front and back-ends. Thus, it is
35 another objective of the present invention to minimize the
number of frequency sources required for the transmitter and
the receiver front and back-end.

5 SUMMARY OF THE INVENTION

10 The present invention is a transceiver that can process signals in multiple bands, requiring a reduced number of frequency sources and filters. The dual band transceiver requires only two frequency sources to accomplish the entire front and back-end of the transmitter and receiver section. Thus, one inventive aspect of the present invention is the reduced number of frequency sources. A second inventive aspect is at least one of the frequency sources has an expanded frequency range, enabling the transceiver to handle an increased number of frequency bands. The advantage of the present invention, and the aforementioned inventive aspects, is a reduced number of components (including frequency sources and filters), and cost.

15 The frequency of the transmit and receive channels are separated by the off-set of the frequency sources. The first frequency source is fed to both the input transmitter mixers, which also receive the I and Q inputs. Each of the transmitter mixers individually combine the first frequency source output and the input signals (unmodulated I and Q transmit signal). The output of the input transmitter mixers are summed together to form a modulated signal (IF transmit signal). The IF transmit signal is the input to a first band and a second band output transmitter mixer. In addition, the second frequency source has a direct electrical connection to 20 the first band output transmitter mixer and is connected to the second band output transmitter mixer through a frequency scaler. If the transceiver is in a first band, the second frequency source signal is combined with the IF transmit signal, resulting in a transmitter output signal (RF transmit signal) corresponding to the first band. However, when the transceiver is operating in the second band, a scaled second frequency source signal is combined with the IF transmit 25

5 signal by the second band output transmitter. The result is
an RF transmit signal corresponding to the second band.

10 The two frequency sources are also utilized for the
receiver section of the transceiver. If the transceiver is
operating in a first band, the first band input receiver mixer
combines the input signal (RF receive signal) with the second
frequency source signal, to obtain a first IF receive signal.
If the transceiver is operating in a second band, the second
band input receiver mixer combines the RF receive signal with
a scaled second frequency source signal, to obtain a first IF
receive signal. In another exemplary embodiment, the first IF
receive signal is down-converted again to obtain a second IF
signal. Finally, the IF receive signal (or second IF receive
signal) is combined with the first frequency source signal, to
obtain an output receiver signal (unmodulated receive signal).
By using a programming means to set the frequency of the first
and/or second frequency source, and by using scalers to obtain
specific frequencies, the transceiver may operate in both
bands.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram **100** that illustrates an
exemplary embodiment of the present invention.

Fig. 2 is a detailed schematic diagram **200** illustrating
the components and functional blocks necessary in an exemplary
embodiment of the present invention.

DETAILED DESCRIPTION

Fig. 1 is a block diagram **100** that illustrates an
exemplary embodiment of the present invention, capable of
transmitting and receiving in a first and second frequency
band. Certain signals which may be present while transmitting
and receiving in one band, may not be present while operating

5 in the second band. In implementing the present invention, there were certain assumptions made about the baseband processor:

- 10 1. The baseband can modulate both digital signals and FM analog signals through the transmitter I and Q inputs of the modulator. The digital signals can be in the form of $\Pi/4$ DQPSK, GSM, 8-PSK or any digital modulation scheme that could be utilized in a TDMA system. This ability to modulate both digital and FM analog signals allows the same IF oscillator to be shared between the receiver and transmitter, since the IF oscillator is not modulated directly during FM mode.
- 15 2. Both digital signals and FM analog signals are demodulated in the quadrature demodulator in the receiver and outputted through the receiver I and Q outputs to be further processed by the baseband.
- 20 3. In digital mode, the RF Phase Locked-Loop (PLL) can be programmed by the baseband processor to change frequency between the receive and transmit slots. For Time Division Multiplexing (TDMA) systems, the receiver and transmitter do not operate simultaneously and the RF PLL can change frequency as long as the frequency is settled before the receive and transmit slots time periods.

25 The first frequency source 105 is used as the oscillating source for upconverting the incoming transmit signal which is applied at the input 139. The incoming transmit signal is a digitized representation of a voice or data signal. The first
35 frequency source 105 has an output 106 which is electrically coupled such that its signal is applied at the input 133 of the back-end transmitter mixer 130. The first frequency source 105 may be a voltage controlled oscillator (VCO) or other frequency source capable of providing the frequency
40 necessary for the upconversion of the incoming transmit signal. The frequency source of this embodiment is stabilized by a phase-locked loop configuration, which is known to those skilled in the art.

While operating in the first band, the back-end
45 transmitter mixer 130 upconverts (combines) the incoming

5 transmit signal and the frequency from the first frequency
source 105. As is known in the industry, the input 139 to the
back-end transmitter mixer 130 may take on a variety of forms
but a common form includes an in-phase "I" signal and an out-
of-phase "Q" signal. The output 137 of the back-end
10 transmitter mixer 130 is an IF transmit signal. Those skilled
in the art will realize the IF transmit may also have been
filtered to obtain the necessary frequency for downstream
processing. Filtering techniques are known by the skilled
artisan, and are not detailed in block diagram 100. Along with
the frequency sources, the present invention reduces the
number of filters needed by using common transmit and receive
IF paths for any band.

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The IF transmit signal from the back-end transmitter
mixer 130 is electrically coupled to the first input 145 of
the front-end transmitter mixer 135. The front-end
transmitter mixer 135 also has a second and third input. A
second input 111 of the front-end transmitter mixer 135 is
electrically coupled to the output 112 of the second frequency
source 110. This connection provides the second oscillating
25 signal to the front-end transmitter mixer 135 during operation
in the first band. In one embodiment, the second frequency
source 110 is programmable, and capable of oscillating over a
range of frequencies. While the transceiver is operating in
the first band, the front-end transmitter mixer combines the
30 IF transmit signal and the second oscillating signal to obtain
a final transmitter frequency corresponding to the first band
at the output 147.

When the invention is operating in the second band, the
operation is basically similar to the operation in the first
35 band; however, the differences are included below. The back-
end transmitter mixer 130 combines the input transmit signal
at a first input 139 and the first oscillating signal from the
first frequency source 105 at a second input 133 of the back-

end transmitter, to generate an IF transmit signal at the output 137. This IF transmit signal is then provided to the input 145 of the front-end transmitter mixer 135. When the transceiver is operating in the second band the output 112 of the second frequency source 110 is passed to the input 141 of a frequency scaler 115. A scaler is a device that multiplies or divides a frequency at its input to provide a scaled frequency output in accordance with its multiplication or division factor. The signal at the output 143 of the frequency scaler 115, the scaled second oscillating signal, is provided to the input 119 of the front-end transmitter mixer 135. The front-end transmitter mixer 135 combines the IF transmit signal and the scaled second oscillating signal, to generate at its output 147, the final transmitter frequency corresponding to the second band. Regardless of which band the transceiver is operating in, the front-end transmitter mixer 135 receives the same IF transmit signal at input 145.

In addition to transmitting in a first and second band, the transceiver also receives in a first and second band. While operating in the first band, the second frequency source 110 generates the second oscillating signal corresponding with the first band. The second frequency source 110 has an output 112 which is electrically coupled to a first oscillating input 113 of the front-end receiver mixer 120.

While the transceiver is operating in the first band, the front-end receiver mixer 120 receives the second oscillating signal from the second frequency source 110 at the first oscillating input 113. RF receive signals are received at the RF input 121 of the front-end receiver mixer 120 and are combined with the second oscillating signal to generate an IF receive signal at output 123.

When the transceiver is operating in the second band, the second frequency source 110 provides an oscillating signal at its output 112 to the second oscillating input 117 of the

front-end receiver mixer 120 through the scaler 115. The oscillating signal at the output 112 of the second frequency source 110 is electrically coupled to the input 141 of the scaler 115. The output 143 of the scaler 115 is electrically coupled to the second oscillating input 117 of the front-end receiver mixer 120. Thus, the front-end receiver mixer 120 receives the scaled second oscillating signal corresponding to the second band and mixes this oscillating signal with the RF signal to generate an IF receive signal.

The IF output 123 of the front-end receiver mixer 120 is electrically coupled to the IF receive input 127 of the back-end receiver mixer 125. If the transceiver is operating in the first band, the back-end receiver mixer 125 receives an IF receive signal generated by combining the second oscillating signal and the RF receive signal. Similarly, if the transceiver is operating in the second band, the back-end receiver mixer 125 receives an IF receive signal generated by combining the scaled second oscillating signal and the RF receive signal. The IF receive signal is the same input to the IF receive input 127, no matter which band the transceiver is operating in at the time.

In addition to the IF input 127, the back-end receiver mixer 125 also has an oscillating input 129 electrically connected to the output 106 of the first frequency source 105. Regardless of which band the transceiver is operating, the back-end receiver mixer 125 receives the same IF receive signal at the IF input 127 and combines it with the first oscillating signal at oscillating input 129. The output 131 of the back-end receiver mixer 125 is an unmodulated receiver signal (baseband) corresponding to the appropriate band.

It should be noted that other embodiments of this invention could be implemented with formats other than TDMA, including GSM, EDGE, and CDMA formats.

Fig. 2 illustrates a detailed schematic diagram 200 of an exemplary embodiment of the present invention. In general, the schematic can be viewed as including a transmitter path 243, a receiver path 245, and two frequency sources 205 and 210. The first frequency source 205 is preferably connected in a phase-locked loop configuration. The first frequency source 205 is also preferably programmable to oscillate at a range of frequencies. Note, the transmitter shown in diagram 200 uses the same transmitter Intermediate Frequency for both bands. In an alternative embodiment, the second frequency source 210 includes a voltage doubler 240 to extend the tuning range of the frequency source. The voltage doubler 240 would be electrically coupled to the output of the RF phase-locked loop 239 and allow the control signal to the second frequency source 210 to have a greater frequency range.

The details of figure 200 are best considered by discussing the components which are common to the transmitter path 243 and the receiver path 245. Discussion of the common components will be followed by discussing the first and second band operation of the transmitter path 243, and finally the first and second band operation of the receiver path 245.

The first frequency source 205 and the second frequency source 210 are common to the transmitter path 243 and the receiver path 245. The frequency of the first frequency source 205 is maintained by the IF Phase Lock Loop circuitry 241.

Similarly, the frequency of the second frequency source 210 is maintained by the RF Phase Lock Loop circuitry 239.

The I and Q inputs (baseband) are the inputs to the first transmitter mixer 209 and the second transmitter mixer 211 associated with the transmitter path 243. In addition, the first transmitter mixer 209 and the second transmitter mixer 211 are electrically coupled to the input of a first frequency scaler 207 associated with the transmitter path 243. The first frequency scaler 207 receives a first oscillating signal

from the first frequency source 205 and provides a scaled first oscillating signal to the first transmitter mixer 209 and the second transmitter mixer 211. Those skilled in the art will recognize that the two mixers are in a typical 90 degree phase shift from one another as is standard in processing I and Q components of a signal. Thus, both mixers will combine their respective transmitter signal inputs with the scaled first oscillating signal and their respective outputs will be summed together in summation device 233. The summation of the respective first and second transmitter mixers form an IF transmit signal. Depending on the band of operation of the transceiver 200, the IF transmit signal will be the input to either the third transmitter mixer 213 or the input of the fourth transmitter mixer 215. The third transmitter mixer 213 and the fourth transmitter mixer 215 are used to convert the IF transmit signal to RF.

The second input to both the third transmitter mixer 213 and the fourth transmitter mixer 215, is the second oscillating signal, which is the output of the second frequency source 210. The second frequency source 210 is preferably a programmable frequency source with a capability to oscillate in a range of frequencies.

As previously mentioned, the transceiver 200 can operate in multiple bands, referred to for convenience as a first band and a second band. While operating in the first band, the path for converting the IF signal to an RF signal includes a third transmitter mixer 213. The third transmitter mixer 213 will combine the IF signal with the second oscillating signal from the second frequency source 210. During operation in the first band, the fourth transmitter mixer 215 is disabled.

Skilled artisans may use one of several common techniques to disable the fourth transmitter mixer 215 at the appropriate time, but the present invention is not concerned with details of which technique is used. The output 235 of third

transmitter mixer 213 is an RF transmit signal corresponding to the first band. This RF signal may be subsequently provided to antenna circuitry (not shown) for transmission.

Similarly, if the transceiver 200 is operating in a second band, the second oscillating signal from the second frequency source 210 is the input to the fourth transmitter mixer 215, through a second frequency scaler 217. The input to the second frequency scaler 217 is the second oscillating signal from the second frequency source 210. The output of the second frequency scaler 217 is a scaled second oscillating signal, which is the input to the fourth transmitter mixer 215. The fourth transmitter mixer 215 will combine the IF transmit signal with the scaled second oscillating signal. The output 235 of the fourth transmitter mixer 215 is an RF transmit signal corresponding to the second band.

As previously described, in addition to the capability of transmitting in a first and second band, the transceiver is capable of receiving in a first and second band. The first receiver mixer 219 and second receiver 221 mixer are located in the receiver path 245, and are used for converting the RF to IF. The second frequency source 210 is electrically connected to the both the first receiver mixer 219 and second receiver mixer 221. However, the second frequency source 210 is electrically coupled to the second receiver mixer 221 through a second frequency scaler 217. In addition, both the first receiver mixer 219 and second receiver mixer 221 have an RF input 237, and their respective outputs are electrically coupled to the first input of a third receiver mixer 223.

When the transceiver 200 is operating in the first band, the second frequency source 210 has an output of a second oscillating signal. The second oscillating signal is the input to the first receiver mixer 219; however, if necessary the second oscillating signal may be scaled. In addition, the first receiver mixer 219 receives an RF incoming signal 237 on

5 a second input. The first receiver mixer 219 combines the RF incoming signal 237 and the second oscillating signal. The output of the first receiver mixer 219 is a first receiver IF. Thus, the first receiver IF is the input to the third receiver mixer 223.

10 However, when the transceiver 200 is operating in the second band, the output of the second frequency source 210, a second oscillating signal, is connected to the input of the second frequency scaler 217. The output of the second frequency scaler 217 is a scaled second oscillating signal. Thus, the scaled second oscillating signal is the input to the second receiver mixer 221. In addition, the second receiver mixer 221 receives an RF incoming signal. The second receiver mixer 221 combines the RF incoming signal and the scaled second oscillating signal. The output of the second receiver mixer 221 is the first receiver IF, which is connected to the third receiver mixer 223. Thus, the input to the third receiver mixer 223 is the first receiver IF. It should be noted that the first receiver mixer 219 is not operational when the transceiver 200 is operating in the second band, nor is the second receiver mixer 221 operational while the transceiver 200 is operating in the first band.

15 In addition to receiving the first receiver IF signal, the third receiver mixer 223 also has a second input which is electrically connected to the first frequency source 205, through a third frequency scaler 225. The first frequency output of the first frequency source 205 is the input to the third frequency scaler 225. The output of the third frequency scaler 225 is a scaled first oscillating signal. Thus, the scaled first oscillating signal is the second input of the third receiver mixer 223.

20 The third receiver mixer 223 combines the scaled first oscillating signal and the first receiver IF signal, regardless of which band the transceiver 200 is operating in

at the time. The output of the third receiver mixer **223**, is a second receiver IF, electrically connected to the fourth receiver mixer **227** and the fifth receiver mixer **229**.

The fourth receiver mixer **227** and fifth receiver mixer **229** are 90 degrees out of phase with one another and arranged in the common form of in-phase "I" signal and an out-of-phase "Q" signal, which is known by the skilled artisan. Thus, further details of the I and Q arrangement are herein omitted.

A second input to the fourth receiver mixer **227** and fifth receiver mixer **229** is a scaled first oscillating signal from the first frequency source **205** through a fourth frequency scaler **231**. The input to the fourth frequency scaler **231** is the first oscillating signal from the first frequency source **205** and its output is a scaled first oscillating signal which is the input to the fourth receiver mixer **227** and fifth receiver mixer **229**. When the transceiver **200** is functioning in either the first or second band, the fourth receiver mixer **227** and the fifth receiver mixer **229** each individually receive and combine the second receiver IF (received from the third receiver mixer **223**) and the scaled first oscillating signal (received from the output of the fourth frequency scaler **231**). The fourth receiver mixer **227** and the fifth receiver mixer **229** produce an unmodulated receive signal (baseband) on their respective receiver I and Q outputs, which may be further processed in the baseband processor (not shown).

Alternate embodiments will become apparent to those skilled in the art to which the present invention pertains without departing from its spirit and scope. Accordingly, the scope of the present invention is described by the appended claims and supported by the foregoing description.